- The Hatfield switching model is more detailed and comprehensive than the BCM2, but given that the results are virtually identical, it is not clear if that level of detail is necessary for USF purposes.

Recommended questions for the BCM2 and Hatfield Model sponsors regarding switch deployment

1. Can a straightforward algorithm (e.g., reflecting distance and number of lines served) be adopted that would reflect the trend toward switch consolidation and the fact that today's switch classification may not be forward-looking?

2. How important is the detail in the Hatfield Model in sizing the USF?

3. What is the basis for the assumption that all the non-traffic sensitive investment (i.e., 70% of traffic) is assigned to local service?

4 THE HATFIELD MODEL'S DEPLOYMENT OF OUTSIDE PLANT

Comparison of outside plant assumptions in the Hatfield Model and BCM2

The Hatfield Model incorporates what its developers term the "BCM-Plus Data Module" and the "BCM-Plus Loop Module." These two modules are nearly identical to the "Data Module" and the "Loop Module" in the original BCM which together modelled the outside plant portion of the network. Thus the foundation for the development of outside plant in the Hatfield Model is nearly identical to that of the original BCM.[60] However, the basic network structure that is developed in these two modules is augmented in later modules of the Hatfield Model to include many additional network elements that were not included in the original BCM and may or may not be included in the BCM2. For example, the Hatfield Model's Wire Center Investment Module adds interoffice network elements that were not included in the BCM and were only partially accounted for in the BCM2. Furthermore, in some cases, the Hatfield Model does not utilize elements of the "BCM-Plus Data Module" and the "BCM-Plus Loop Module" even though these elements have not been removed from the Modules. For example the "BCM-Plus Data Module" develops the same structure cost multipliers as did the original BCM, but these multipliers are not relied on by the Hatfield Model. Instead, the Hatfield Model employs per foot investments for copper and fiber cable that include engineering, delivery, and installation in addition to the cost of raw materials. The Hatfield Model also includes additional costs related to structure and conduit expense which obviate the need for the structure multipliers in the "BCM-Plus Data Module."

Density zones

The Hatfield Model categorizes CBGs as belonging to one of six density zones as did the BCM and the BCM2. However, the density calculation in the Hatfield Model is made on the basis of total lines — residential, business, special access and public — while the

60. For a detailed description of the development of outside plant in the BCM, see the April Report, at 17-26.

density zones in the BCM2 are a function of the CBG's residential lines and a fractional portion of its business lines only.[61] Comparisons of the two models' results by density zone will thus be imperfect to the extent that some CBGs would be grouped into different density zones by each of the two models.[62] This attribute of the two models is discussed in more detail in Chapter 1.

Feeder technology

The Hatfield Model, like the BCM and the BCM2, assumes that CBGs are served by either copper or fiber feeder plant. CBGs are first assigned to the closest existing central office site and then to one of four switch "quadrants." Switch quadrants are marked by the area surrounding the main feeder plant which is assumed to extend from each central office site in four directions (due east, north, west and south). CBGs that are mapped to the same switch quadrant share the same main feeder route and so each main feeder segment is modelled to handle the capacity requirement of the CBGs further out along the main feeder route which utilize the same feeder technology. Each CBG is served by dedicated subfeeder plant which branches off the main feeder route at ninety degree angles and terminates halfway between the CBG's center and its edge.

The Hatfield Model's placement of a single Service Area Interface (SAI) per CBG halfway between the edge of the CBG and the CBG's center marks a departure from the BCM2, which in most cases locates the SAI (or "remote terminal") on the CBG's edge. The BCM2 will place one or more remote terminals inside the CBG when the CBG's distribution requirement exceeds a user specified "maximum copper distribution distance." The default maximum copper distribution distance is 12,000 feet. Thus, when a CBG's distribution requirement exceeds that benchmark, feeder is automatically extended into the CBG, creating, in effect, multiple distribution areas inside the CBG which are served by multiple feeder legs. We tested the frequency of multiple feeder legs within the distribution area of CBGs in a default run of Washington State and found that slightly more than 5% of the CBGs required more than one feeder leg. We then determined that the BCM2 assigned an average of 2.2 remote terminals to the 4,618 CBGs in Washington State.

61. The density zones in the BCM2 are defined by first dividing the CBG's business lines by the "density adjustment unit" (default level 10), and then dividing the sum of the adjusted business lines and the CBG's number of households by the area in square miles.

62. The original BCM calculated density on the basis of households only.

Copper/fiber crossover algorithm

The Hatfield Model assigns either copper or fiber feeder to CBGs on the basis of the total feeder length. The "copper/fiber crossover point" is a user-specified input with a default value of 9,000 feet. Thus CBGs with feeder lengths less than 9,000 feet are assigned copper feeder while CBGs with feeder lengths that exceed 9,000 feet are assigned fiber feeder. Furthermore, the Hatfield Model, like the BCM and the BCM2, includes two different digital loop carrier (DLC) systems — AFC and SLC. The Hatfield Model Sponsors indicated in their response to questions posed by the Joint Board that the Hatfield Model assigns AFC to CBGs in the lowest two density zones and SLC to CBGs in the four largest density zones.[63] However, our examination of the algorithm in the BCM-Plus Loop Module that selects a feeder technology indicates that AFC is assigned only to CBGs which require feeder and which belong to the lowest density zone. We have not identified any algorithm in a later module where this initial assignment of a feeder technology may be corrected.

The Hatfield Model's use of the CBG's feeder distance only as the "crossover benchmark distance" (i.e., the network component or components that are referenced by the copper/fiber crossover algorithm) marks a significant change from the original BCM and the BCM2. Both the BCM and the BCM2 include distribution plant in their respective copper/fiber crossover algorithms, however, they do so in different ways. The BCM copper/fiber crossover algorithm compared the CBG's total feeder length plus a measure of the *average* distribution distance with a default copper/fiber crossover point of 12,000 feet. The average distribution distance was calculated as 0.75 times the CBG's width. The copper/fiber crossover algorithm in the BCM2 does not reference the CBG's average distribution distance, but rather its *maximum* distribution distance. The "Maximum Distribution Distance" in the BCM2 is measured as 1.5 times the CBG's width less two times the "Base Lot Side Length."[64] Thus, in the BCM2, the same default copper/fiber crossover distance of 12,000 feet is compared with the CBG's total feeder distance plus an estimate for the CBG's maximum distribution distance.

In order to better understand the effect of the different crossover benchmark distances utilized in the copper/fiber crossover algorithms of the Hatfield Model, the original BCM and the BCM2, we calculated the average distance of the relevant network components referenced in each of the three algorithms for a default run of Washington State. Table 4.1 below shows the results of this analysis and includes the same calculation for a run of BOC-only data in the BCM2 to provide an even closer comparison to the Hatfield Model.

63. AT&T/MCI Supplemental Response, *op. cit.*, footnote 10, at 16.

64. The CBG's Base Lot Side Length is the average length of a housing lot and is calculated by dividing the CBG's width by the square root of the CBG's number of households.

Table 4.1

Comparison of Average Distances Referenced by Copper/Fiber Crossover Algorithms

	BCM	**BCM2**	**BCM2 BOC**	**Hatfield**
Main Feeder	10,641	10,648	9,195	9,212
Sub-feeder	1,720	1,897	2,085	2,637
Distribution	7,317	10,640	6,862	N/A
Total	19,678	23,185	18,142	11,849
Default crossover point	12,000	12,000	12,000	9,000

Notes:
1. BCM distribution measure equals "average distribution" = 0.75 * D (width of CBG).
2. BCM2 distribution measure equals "maximum distribution distance" = (1.5 * D) - 2 * "Base Lot Side Length."
3. Hatfield Model does not reference distribution in its copper/fiber crossover algorithm.

As seen from Table 4.1, the average *maximum* distribution distance calculated for Washington State by the BCM2 was 10,640 feet, considerably higher than the 7,313 foot *average* distribution distance calculated for Washington by the original BCM. Furthermore, the average length of the total relevant distance for the BCM2 of 23,185 feet is nearly double the default copper/fiber crossover point of 12,000 feet. As a means of further analyzing the impact of the different crossover benchmarks utilized by the three models, we tabulated the incidence of each feeder technology type produced by default runs of each model for Washington State. The results of this analysis are presented below in Table 4.2.

Table 4.2

Incidence of Copper and Fiber Feeder in Default Runs of the Hatfield Model, BCM and BCM2 for Washington State

	BCM		BCM2		BCM2 BOC		Hatfield	
	CBG	%	CBG	%	CBG	%	CBG	%
Copper	2,043	45%	1,633	36%	1,217	41%	1,333	47%
SLC	2,223	49%	2,277	49%	1,494	51%	1,536	52%
AFC	276	6%	708	15%	225	8%	32	1%
Total	4,542	100%	4,618	100%	2,936	100%	2,902	100%

Table 4.2 shows that the original BCM and the Hatfield Model both assign copper feeder to approximately 45% of the CBGs in default runs of Washington State input data. In contrast, the BCM2 assigns copper feeder to only 36% of the total CBGs in Washington State and a slightly higher 41% of the CBGs in a run of BOC input data only. The lower incidence of copper feeder in the BCM2 can be largely attributed to the use of the *maximum* distribution distance in the copper/fiber crossover algorithm as opposed to the *average* distribution distance as in the original BCM. We recommend that the Joint Board request further information from the Sponsors of the BCM2 on their rationale for making this adjustment to the copper/fiber crossover algorithm. We also recommend that the Joint Board request further information from the Sponsors of the BCM2 and the Hatfield Model on the relative merits of deploying copper or fiber feeder on the basis of the feeder length alone or on the combined length of the feeder and some measure of the distribution plant.

Although the "Main Logic" worksheet of the BCM2 is password protected, we copied the columns of data referenced by the copper/fiber crossover algorithm to a new spreadsheet file in order to test the sensitivity of the algorithm to alternative "crossover benchmark distances." For example, we set the "crossover benchmark distance" equal to the CBG's feeder alone (i.e., excluded the distribution component of the algorithm to more closely align with the copper/fiber crossover algorithm in the Hatfield Model) so that copper feeder was assigned to CBGs with a feeder length less than 12,000 feet. Not surprisingly, the proportion of CBGs assigned copper feeder under the shorter "crossover benchmark distance" increased from the default level of 36% to 61%. In other words, 61% of the CBGs in Washington State had feeder lengths that were less than the default copper/fiber crossover point of 12,000 feet. As a separate analysis, we then increased the crossover benchmark distance to (1) the feeder length plus 3,000 feet and (2) the feeder length plus

0.75 times the width of the CBG, each time maintaining the default copper/fiber crossover point of 12,000 feet. The results of all three sensitivity analyses are presented below in Table 4.3.

Table 4.3

Alternative Crossover Benchmark Distances in the BCM2 Copper/Fiber Crossover Algorithm

	Default		**Feeder Only**		**Feeder + 3,000 feet**		**Feeder + 0.75 * CBG width**	
	CBG	%	CBG	%	CBG	%	CBG	%
Copper	1,633	36%	2,835	61%	2,140	46%	2,080	45%
SLC	2,277	49%	1,218	27%	1,835	40%	1,839	40%
AFC	708	15%	565	12%	643	14%	699	15%
Total	4,618	100%	4,618	100%	4,618	100%	4,618	100%
Average Crossover distance	23,185 feet		12,544 feet		15,544 feet		18,029 feet	

Note: The BCM2's default copper/fiber crossover point of 12,000 feet was used in all cases.

The analyses presented in Table 4.3 above reflect only changes to the crossover benchmark distance in the BCM2's copper/fiber crossover algorithm. In conducting these sensitivity analyses, we did not alter the capacity requirement component of the BCM2's copper/fiber crossover algorithm. In the BCM2, fiber feeder will be deployed even when the crossover benchmark distance is *less* than the copper/fiber crossover point if the CBG's capacity requirement exceeds the capacity of the maximum size distribution cable (3600).[65] The BCM2's inclusion of a capacity requirement component in the copper/fiber crossover

65. The capacity requirement calculation in the BCM2 copper/fiber crossover algorithm equals the CBG's "Total CBG Lines Served" less the "Lines in CBG Provisioned as DS-1s" plus the CBG's "Lines Provisioned as DS-1s" divided by 12. This result is then divided by the feeder fill factor appropriate to the CBG's density zone. See Column AJ of the "Main Logic" worksheet of the BCM2.

algorithm is an enhancement which does not exist in the Hatfield Model, however, our analysis of this component in the BCM2 revealed that it has very little impact on the assignment of copper versus fiber feeder. In particular, we found that for Washington State, only twenty CBGs (or less than 0.1% of the 4,618 total CBGs) triggered the capacity requirement contained in the BCM2's copper/fiber crossover algorithm.

Several conclusions can be drawn from the analyses of the copper/fiber crossover algorithms of the Hatfield Model and the BCM2 outlined above. First, the BCM2's use of feeder plus *maximum* distribution distance instead of feeder plus *average* distribution distance resulted in an average crossover benchmark distance for Washington State that was 23,185 feet or 18% higher than the average crossover benchmark distance utilized in the BCM. The Sponsors of the BCM2 elected to keep the default copper/fiber crossover point at 12,000 feet and so the change to feeder plus maximum distribution distance in the BCM2 resulted in an approximate 10% increase in the use of fiber feeder for Washington State over what existed in the original BCM and exists in the Hatfield Model. The higher incidence of fiber feeder in the BCM2 likely contributes to total feeder costs in the BCM2 which are nearly twice the feeder costs generated by the Hatfield Model. We found that running the BCM2 with BOC-only data for Washington State produced a total feeder plant investment of $610-million, nearly double the $329-million total feeder investment produced by the Hatfield Model.

Copper/fiber crossover point sensitivity analysis

One test of a model's internal consistency is whether it "chooses" the least cost alternative between deploying copper and feeder as these alternatives are costed out in the model. As we demonstrated in our August Report, the BCM2 fails this fundamental objective.[66] If the chosen copper/fiber crossover point does not accurately represent the least cost, forward-looking method of providing residential basic service, then the estimation of loop investment costs will be overstated. Accordingly, we have conducted sensitivity analyses of this crossover point for the Hatfield Model. Table 4.4 shows the results of this analysis in terms of the relative change to the mohthly costs in each of the six density zones as well as the aggregate statewide average monthly cost for selected crossover points.

66. August Report at 74.

Table 4.4

Sensitivity Analysis of the Copper/Fiber Crossover Point Hatfield Model

Washington State

Density Class	**Total Feeder Distance Measured in Feet**				
	3,000	6,000	9,000	12,000	15,000
<=5	$87.46	$87.45	$87.61	$87.68	$87.79
5-200	31.04	31.14	31.42	32.03	32.71
200-650	19.11	19.17	19.49	20.07	20.60
650-850	16.72	16.78	17.05	17.56	18.33
850-2550	16.22	16.10	16.12	16.37	16.70
>2550	14.62	14.23	14.17	14.33	14.57
Average Cost	$17.67	$17.46	$17.51	$17.79	$18.15

The impact of this choice on the average monthly cost is not dramatic; the average monthly cost over the range of copper/fiber crossover points analyzed varies by only $0.69. There is a minimum cost in the vicinity of 6,000 feet to 9,000 feet. Therefore the Hatfield Model exhibits substantially more internal consistency than the BCM2 does in this respect.[67]

Digital loop carrier

Whenever the Hatfield and BCM2 models select fiber optic facilities in the feeder portion of the network, they also calculate the costs of the accompanying digital loop carrier a(DLC) systems, which are the circuit electronics that provide the multiplexing/de-multiplexing functions used to concentrate traffic onto high-capacity feeder circuits. While Hatfield and BCM2 both model DLC investments at a detailed level, their developers have

67. If, however, the user increased the default inputs for the DLC investment, the economic crossover point would shift, therefore requiring a different crossover point to preserve the model's internal consistency.

chosen to emphasize different factors bearing on DLC investment costs. In addition, the model developers have made significantly different assumptions regarding DLC systems' maximum capacity, common equipment costs, and per-circuit costs. Despite these differences, however, the two models produce estimates of DLC investment costs that are similar in many respects, with the most important divergence being that BCM2 assumes a significantly higher overall cost level (or, alternatively, a smaller vendor discount) for the larger-sized DLC systems than does the Hatfield model. This difference appears to be an important driver of the substantially higher overall cost for feeder plant estimated by the BCM2 compared to the Hatfield model (see page 71). Our analysis is described in more detail below.

Each of the two models develops DLC investment costs on a CBG-by-CBG basis, assuming that one or more DLC systems are required to serve a CBG, but that no DLC system will serve multiple CBGs.[68] Both models also make a primary distinction between the DLC equipment used in most CBGs, and the smaller-capacity equipment required to serve rural, less populated CBGs. Furthermore, the models agree in choosing the vendor Advanced Fiber Communications (AFC) to represent the DLC equipment deployed in the latter CBGs.

The models differ, however, in applying contrasting decision rules to govern when AFC systems are selected: the BCM2 chooses the AFC system whenever a remote terminal serves less than 240 lines, while the Hatfield model chooses AFC for all remote terminals in density zones 1-2.[69] In our view, a decision rule based on remote terminal capacity is more appropriate than one based on CBG density, since it more closely reflects least-cost engineering. For example, a density rule will assign a larger-capacity non-AFC system in CBGs having a small total area and line count, but a moderate density, when a smaller-capacity AFC system would be less costly. Thus, the Hatfield model appears to overstate DLC investment costs in this respect, although we have not yet analyzed the magnitude of this effect.

The two models also apply different calculation algorithms and default input values to estimate the costs of an AFC system (see Table 4.3 for details of the default inputs; the algorithms have the same form as those for non-AFC investments, see below). For example, the Hatfield model assumes a considerably smaller maximum capacity (100 lines vs. 239 lines) and smaller variable investment per line ($150 vs. $250) for the AFC system than does BCM2 (see Table 4.3). To evaluate the impact of these apparent differences, we

68. In reality, LECs deploy DLCs to serve defined "carrier serving areas" (CSAs), not CBGs. To date, we have not determined whether this simplifying assumption introduces any systematic bias to either models' results.

69. As explained on page 67, to date we have not confirmed that AFC is chosen in zones 1-2 rather than zone 1 only.

calculated the total AFC system cost for a range of system sizes (i.e., CBG line counts), as generated using the models' basic AFC costing algorithms and default inputs. The results are provided in Figure 4.1, expressed in terms of the DLC investment dollars per line served in the CBG. As Figure 4.1 demonstrates, the two models produce similar investment cost curves for AFC systems under their default assumptions. Therefore, the models' varying approaches to estimation of AFC investments do not explain differences in their overall estimates of universal service costs.

The Hatfield and BCM2 models diverge more in their choices for DLC equipment where AFC systems are not used. The BCM2 assumes use of AT&T (now Lucent Technologies) SLC Series 2000 systems of three discrete size increments (from 240 to 2016 lines capacity) to represent non-integrated DLC technology widely deployed by the BOCs.[70] In contrast, the Hatfield model assumes use of a 672-line capacity *integrated* DLC (IDLC) system conforming to the TR303 interface standard, which is a more advanced, next-generation technology that is generally available but not in widespread use to date. In addition to this technology choice, the models' algorithms differ in several details. The Hatfield model's algorithms include explicit factors for line fill and ancillary investments (site, housing and power for the remote terminal) that are not included in BCM2. The BCM2 includes an explicit factor for the costs of engineering, furnishing, and installation (EFI) of DLC plant which increases the base cost by 35% above the nominal levels appearing in Table 4.5, while the Hatfield model does not apply an explicit EFI factor. BCM2's algorithm also accounts for the economies that occur when a portion of the demand in a CBG is associated with digital PBXs or high-capacity dedicated services, by costing out direct terminations at the DS-1 level.[71] This refinement appears to have little impact, however, since in our default run on Washington state (BOC and independent CBGs), it was triggered in only 3.2% of the CBGs (150 out of 4,618) in the state.[72]

Figure 4.2 presents the DLC investment curves produced by applying the Hatfield and BCM2 models' default inputs to their algorithms for non-AFC systems (i.e., SLC 2000 vs. IDLC). Comparison of the two curves shows that they are similar in overall form, but that the Hatfield model's approach results in significantly lower per-line DLC investments than does the BCM2. Moreover, we found that increasing the BCM2's discount factor for DLC investments from 20% to 50% (with no further changes made) results in a much closer agreement of the two models' default DLC investment curves (see Figure 4.3), particularly as increasing line counts reduce the impact of their differing common cost assumptions.

70. In a non-integrated DLC system, feeder circuits are terminated at a central office terminal (COT) before passing into the end office switch, whereas an integrated DLC has a direct interface into the switch. See BellCore, *BOC Notes on the LEC Networks — 1994*, Section 12 at 18-24.

71. See the *BCM2 Methodology* documentation at 3.

72. Accordingly, this refinement is not reflected in the DLC investment curves presented in Figures 4.1-4.3.

While this latter agreement may be coincidental, it appears to indicate that the choice of non-integrated DLC vs. IDLC may reflect differences in vendor discounting as much as the two technologies' undiscounted price levels. In any case, the models still diverge significantly in the portion of the DLC investment curves having the greatest impact on cost levels, i.e. for CBGs that have 240 to 1000 lines (in our default Washington state run of the BCM2, 72% of CBGs have under 800 lines, and nearly half have under 600 lines).

Recommendations regarding DLC

In general, our analysis has revealed more similarities than differences in the Hatfield and BCM2's modeling of DLC investment costs. The single greatest difference in this area is the Hatfield model's significantly lower average cost level for non-AFC carrier systems compared to the BCM2. This is a key difference between the models, however, since it appears to drive the substantially lower overall cost for feeder plant estimated by the Hatfield model compared to the BCM2 (see page 71 above). To resolve this issue, regulators will need to focus on (1) whether or not an IDLC system is more appropriate for a forward-looking proxy cost model, (2) the appropriate discount factor to apply to DLC investment, and (3) the most reasonable cost level for DLC systems serving approximately 240 to 1000 lines. While further analysis should be undertaken to evaluate the impact of the Hatfield model's use of a density-based decision rule for choosing AFC technology, our preliminary recommendation is that the Hatfield model should be revised to apply a decision rule based directly on the system size required to meet demand in the CBG as a least-cost practice.

Table 4.5

Digital Loop Carrier Inputs
Cost for AFC/SLC Systems

BCM2 Digital Carrier Cost			Hatfield Digital Loop Carrier Inputs		
Number of Lines	**Fixed Cost**	**Per Line Cost**		**BCM "SLC" (TR-303)**	**BCM "AFC"**
0 - 47	$7,700	$250	Site, housing, and power per RT	$3,000	$2,500
48 - 119	$8,500	$250	Maximum lines	672	100
120 - 239	$10,500	$250	RT fill factor	0.90	0.90
240 - 671	$77,330	$184	Common equipment investment	$42,000	$10,000
672 - 1333	$94,909	$184	Channel unit investment per line	$75	$150
1334 - 2016	$105,409	$184			
DLC Discount		.20			
Engineering/Installation Factor		.35			

Distribution plant

The Hatfield Model develops the distribution plant requirement for each CBG in the "BCM-Plus Data Module" and so the distribution plant in the Hatfield Model mirrors very

Figure 4.1

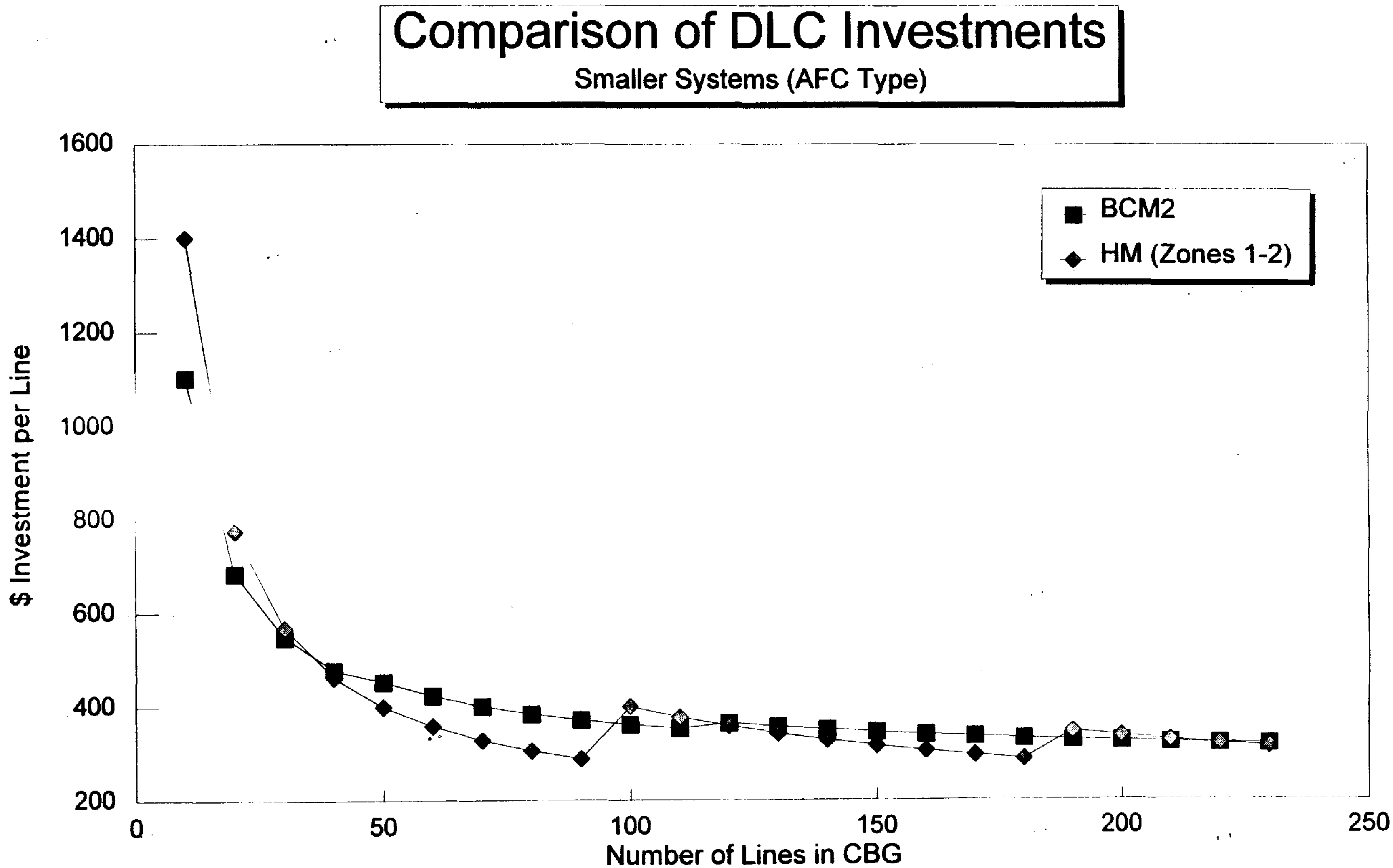

Comparison of DLC Investments
Smaller Systems (AFC Type)
BCM2
HM (Zones 1-2)
$ Investment per Line
1600
1400
1200
1000
800
600
400
200
0
50
100
150
200
250
Number of Lines in CBG

Figure 4.2

Comparison of DLC Investments

Larger Systems (SLC 2000 vs. IDLC)

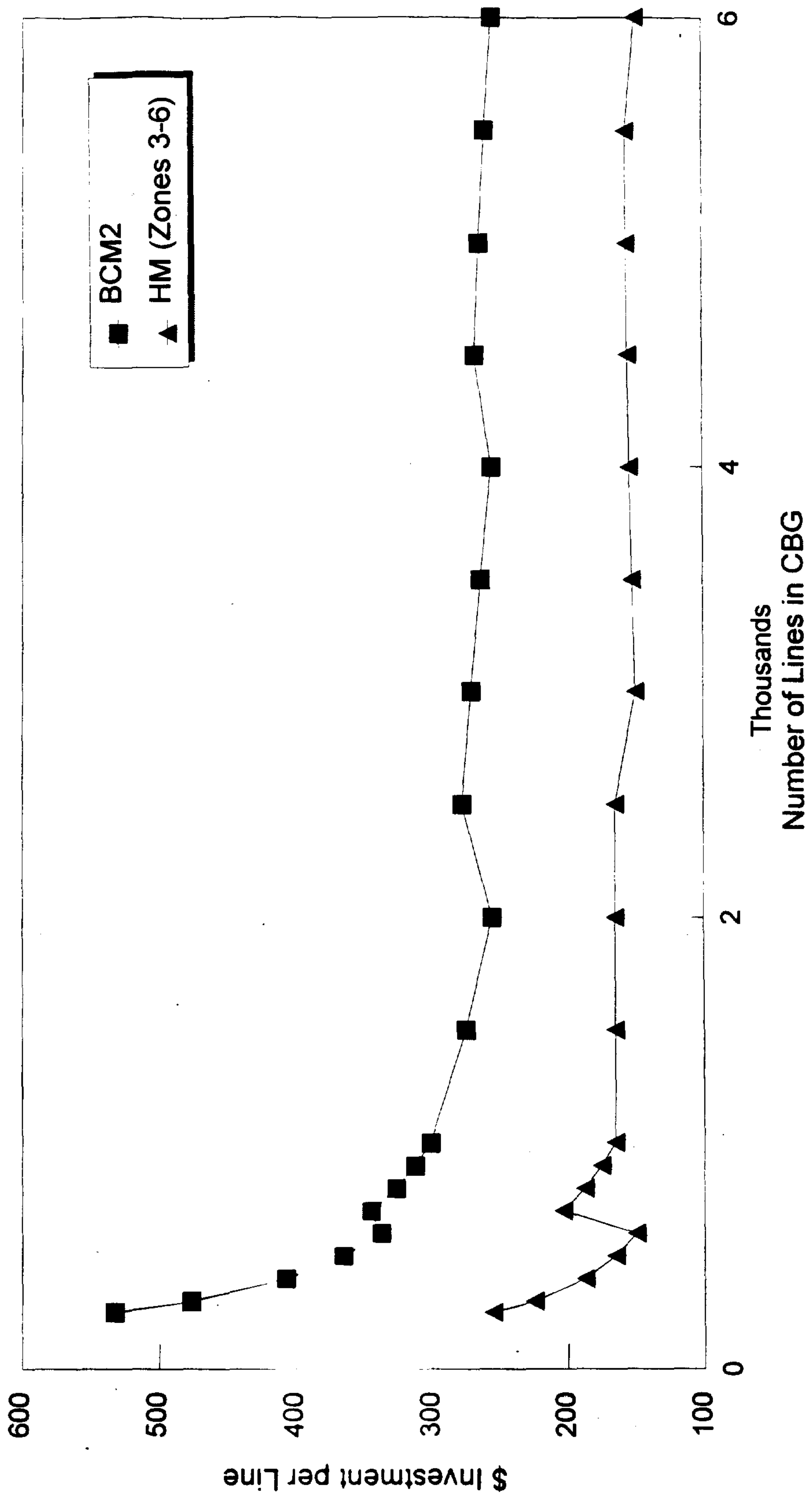
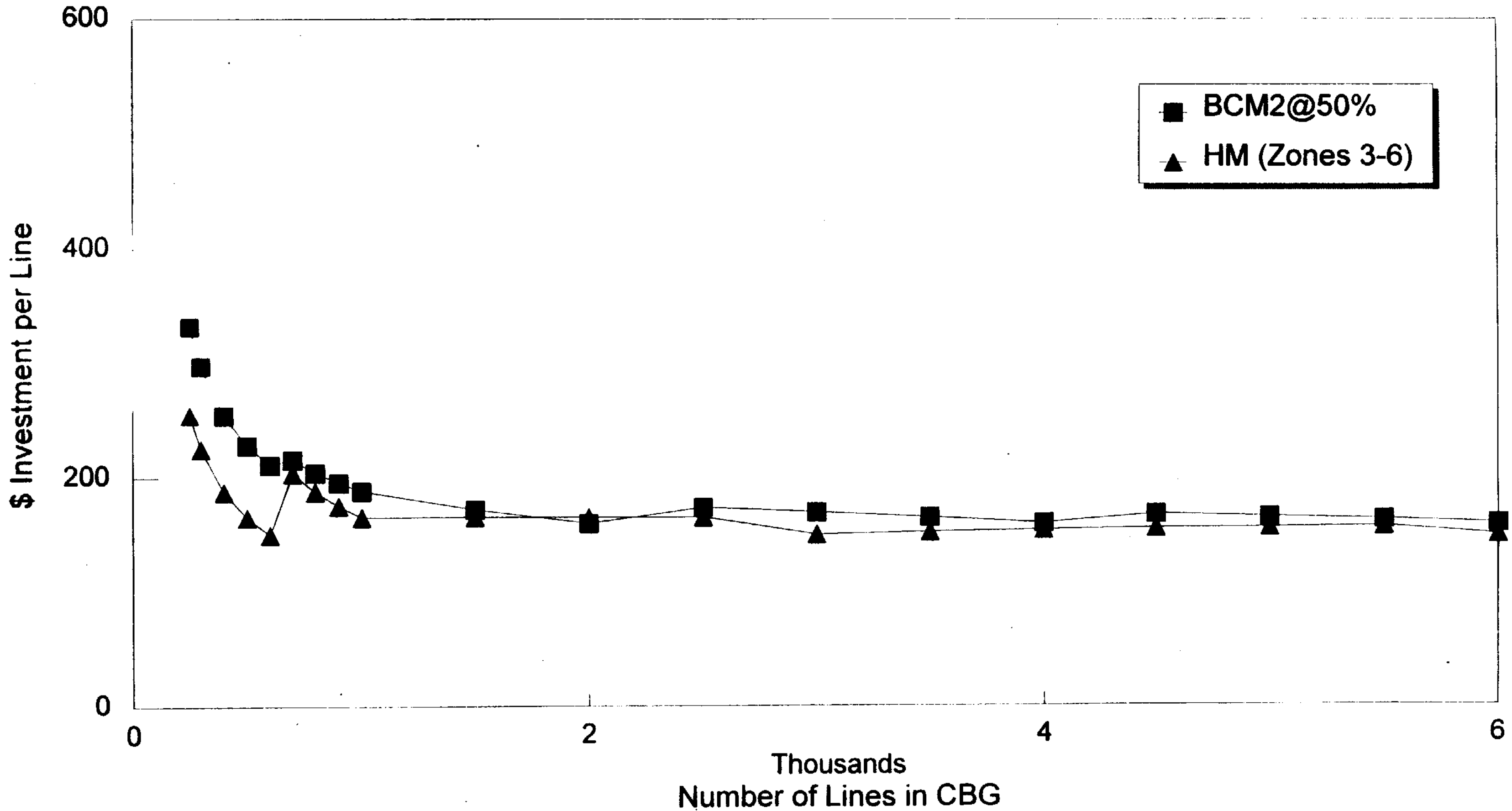


Figure 4.3

Comparison of DLC Investments

Larger Systems (SLC 2000 vs. IDLC) SLC with 50% Discount



closely that of the original BCM. For all three models — the BCM, the BCM2 and the Hatfield Model — the width of a square CBG, the so-called "Segment D" or "Base Side," is the foundation for the development of the CBG's distribution plant requirement. The original BCM assumed that feeder plant terminated at the edge of each CBG and that the CBG's distribution plant requirement could be met by four distribution legs of equal length and capacity. The length of each distribution leg was set equal to 0.75 times the width of the CBG on the assumption that this distance represented the average distance that must be covered in order to pass all of the households in the CBG.

The Hatfield Model adopts this same methodology for assigning distribution plant with only a few modifications. First, the Hatfield Model assumes that feeder plant extends into each CBG to a point half way between the CBG's boundary and its center. Thus the average distribution distance in the Hatfield Model equals 0.625 times the width of the CBG as opposed to 0.75 times the width of the CBG as in the BCM. Furthermore, the Hatfield Model assigns between two and eight distribution legs to each CBG depending on the CBG's density of lines per square mile instead of assigning four distribution legs to each CBG as did the BCM.

The Sponsors of the BCM2 claimed that the BCM did not assign distribution plant sufficient to pass every household in the more densely populated CBGs. As such, in the BCM2, the number of distribution legs is tied to the number of housing lots in each CBG. This marks a departure from the BCM which assumed four equally sized distribution legs for each CBG and the Hatfield Model which assumed between two and eight distribution legs per CBG. We found that the BCM2 assigned as many as 30 distribution legs to a single CBG in Washington State and that an average of 10 distribution legs were assigned throughout the state. Although the number of distribution legs per CBG in the BCM2 is not a direct function of the CBG's density zone as in the Hatfield Model, we computed the average number of distribution legs per density zone in the BCM2 to provide a basis for comparison among the three models. The results of this analysis are presented below in Table 4.6.

Table 4.6

Distribution Legs per Density Zone in the BCM, BCM2 and the Hatfield Model

	Number of Distribution Legs		
Density Zone	BCM	BCM2	Hatfield Model
0 - 5	4	5.0	2
5 - 200	4	9.1	4
200 - 650	4	10.3	4
650 - 850	4	10.7	4
850 - 2550	4	10.6	6
> 2550	4	11.0	8

Notes:
1. Density zones in the BCM are defined by the total households divided by the CBG's area in square miles. Density zones in the BCM2 are defined by the sum of the CBG's households and the "adjusted" number of business lines divided by the CBG's area. Density zones in the Hatfield Model are defined by the total lines (residential, business, special access and public) divided by the CBG's area.
2. The number of distribution legs for the BCM2 equals the average number of distribution legs that were assigned to the CBGs in each density zone in a default run of Washington State input data.

We also compared the total distribution investment estimates produced by both the Hatfield Model and the BCM2, again using RBOC only input data for Washington State. The Hatfield Model produces a total distribution investment level using all default user inputs of $685.3-million. The default BCM2 produces a total distribution investment that is approximately 34% higher than the Hatfield Model or $921.5-million.

The Hatfield Model also mirrors the original BCM insofar as households are assumed to be uniformly distributed throughout each CBG. This assumption was criticized in the original BCM as overstating the distribution plant requirement for large, sparsely populated CBGs in which households are more likely to be clustered together than spread evenly throughout a large area. The Sponsors of the BCM2 addressed this criticism by incorporating a third party database that reduced the area of CBGs with fewer than 20 households to the territory 500 feet on either side of the CBG's road network. The sponsors of the Hatfield Model stated that "a similar enhancement to reflect more accurately the costs in sparsely-populated areas is being developed for a future release of the Hatfield Model."[73]

Structure costs

There are several differences between the methods used by the Hatfield Model and the BCM2 to reflect structure costs. Perhaps most importantly, the Hatfield Model includes a user specified input which assigns a percentage of the structure costs to telephone. In other words the Hatfield Model considers that structure costs are shared among telephone, electric, cable television and other potential service providers. The default percentage in the Hatfield Model is 33% which effectively assigns only one-third of the model's structure costs to telephone plant. The BCM2 does not include a comparable input to account for the sharing of structure costs.

Structure costs in the BCM2 are primarily accounted for through 54 "structure cost multipliers" which represent the structure cost per foot for the three different plant types under various placement conditions. For example, the BCM2's per foot structure cost for underground copper cable in urban areas which exhibit "Rock Hard" conditions is $20.84. The Hatfield Model, in contrast, uses a series of per foot structure cost elements that are each user inputs and which may be varied for copper distribution, copper feeder, and fiber feeder plant as well as by density zone. The default structure cost elements for distribution plant have been reproduced below in Table 4.7. Moreover, the Hatfield Model permits the user to partially assign percentages to aerial, buried and underground facilities such that 100% of the structure costs are allocated among the three plant types.

73. AT&T/MCI Supplemental Response, *op. cit.*, footnote 10, at 10.

Table 4.7

Hatfield Model Structure Cost Elements for Distribution Plant

Element	Unit Cost
Buried Installation/foot	($2 - $20 per foot)
Conduit Installation/foot	($25 - $70 per foot)
Pole Spacing feet	150
Pole Investment	$450
Conduit Investment per foot	$1.00
Manhole Investment per foot	$3,000
Buried Cable Armoring Multiplier	1.1

Related to structure costs are placement costs which are accounted for differently by the Hatfield Model and the BCM2. Placement costs in the Hatfield Model are embedded in the per-foot cable costs for distribution, copper feeder and fiber feeder plant. In the BCM2 placement costs are reflected through at least three user specified inputs. These include: 1) the "UG Pull Cost" variable which reflects the cost per foot to pull the maximum sized cables into conduit; 2) the three "Copper Size Factors" and the "Fiber Size Factor" which reflect additional placement costs associated with larger size cables; and 3) Copper and Fiber Splice Ratios which reflect the costs of splicing cables.

Fill factors

As shown in Table 4.8 below, the feeder and distribution fill factors for the Hatfield Model and BCM2 are not significantly different across the six density zones.

Table 4.8

Comparison of BCM2 and Hatfield Model Default Fill Factors

	Feeder Plant		**Distribution Plant**	
Density Zone	**BCM2**	**Hatfield**	**BCM2**	**Hatfield**
0 - 5	0.75	0.65	0.40	0.50
5 - 200	0.80	0.75	0.45	0.55
200 - 650	0.80	0.80	0.55	0.60
650 - 850	0.85	0.80	0.65	0.65
850 - 2,550	0.85	0.80	0.75	0.70
> 2550	0.85	0.80	0.80	0.75

5 "APPLES-TO-APPLES" RUNS OF THE HATFIELD MODEL AND THE BCM2

Because of the various differences in the design of the Hatfield Model and the BCM2 it is difficult to create a comprehensive "apples-to-apples" comparison, i.e., a comparative run of the two models using, to the extent possible, an identical set of default values. This section summarizes our effort in this area, which entailed making adjustments to both models. The purpose of such an attempt is to identify where the two models diverge by isolating changes relating to inputs from those relating to model design. The question we would like to be able to answer is, if a common set of inputs were run through both models (setting aside the merits of any given set of inputs), how much would the results of the two models diverge? Because of the availability of depreciation data in Utah, we conducted our final apples-to-apples run on the Utah data set. The revisions discussed below *do not reflect the inputs or algorithms that ETI advocates, but rather are simply made for the purpose of attempting to achieve an apples-to-apples comparison of the two models.* Changes were made where they could be accomodated by the model's design. For example, the digital switching discount is "hardwired" into the Hatfield Model, so the BCM2 was adjusted to mirror the Hatfield Model.

Modifications to the BCM2

- As discussed above, because the Hatfield Model presently includes only BOCs and SNET, we stripped away the non-BOC regions of Utah from the BCM2, and then, to avoid a disproportionate focus on the lower-cost CBGs, we analyzed results disaggregated by density zone.

- Because the digital switch discount is not a user-specified variable in the Hatfield Model, we set the digital switch discount to 50% in the BCM2 to equal the implied discount in the Hatfield Model.[74]

74. As is shown in the graph in Chapter 3, Figure 3.1, switch costs have converged greatly and thus we do not believe that differing switch costs explain much of the difference in results.

Modifications to the Hatfield Model

- In the Hatfield Model, we zeroed out the cost of billing/billing inquiries, directory listing, and local number portability expense in order to make the scope of service being modelled more comparable to that modelled in the BCM2.

- Because the individual cost components cannot be user-specified in the BCM2, in the Hatfield Model we set the effective rate of return to 11.25%; the depreciation lives to those approved by the FCC; and the overhead factor to 20% in order to mimic the inferred cost factors in the BCM2.[75]

- Fill factors can be readily changed in both models. We changed the fill factors in the Hatfield Model so that both models used the fill factors for the feeder and distribution plant that are used in the BCM2.

- We changed the Hatfield Model so that 100% (not 33%) of the structure costs are assigned to telephony.

Table 5.1 and Table 5.2 summarize the results of this cross-comparison. Three of the major changes that we did not equalize inputs for are: (1) the quantity of distribution legs, (2) the reclassification of buried plant as underground plant in the Hatfield Model to mimic the two categories of plant that apply in the BCM2, and (3) structure and placement costs. Therefore, although the modified results are more closely aligned than the two default versions of the models, it is important to realize that our cross-comparison does not capture the impact of these three changes.

75. We also performed sensitivity runs on the overhead factor in the Hatfield Model by changing the value to 30% and 40%. The results of the sensitivity analysis yielded a range of an average cost of $26.64 (20% overhead) to $31.08 (40% overhead). We recommend that further analysis be conducted of the relationship between the overhead factor of 10% that is in the Hatfield Model to the non-plant-related expense factor of $8.34 per month that is included in the BCM2.

Table 5.1

Partial Equalization of Default Inputs to Create
an Apples-to-Apples Comparison of the Hatfield Model and the BCM2

Utah

USF Requirement	**BCM2 Modified**	**HM Modified (20% Overhead)**	**HM Modified (30% Overhead)**
$20 Benchmark	$63,091,267	$45,607,298	$60,446,310
$30 Benchmark	26,594,648	29,439,348	34,171,997
$40 Benchmark	16,042,828	20,321,868	25,054,517
Average Cost	$27.89	$26.64	$28.86

Note: See text for description of the various revisions made to each of the models.

Table 5.2

Partial Equalization of Default Inputs to Create
an Apples-to-Apples Comparison of the Hatfield Model and the BCM2

Utah
Results Disaggregated by Density Zone

Density Zone	**BCM2 Modified**				**Hatfield Model Modified (Overhead Factor = 20%)**			
	$20 Benchmark	$30 Benchmark	$40 Benchmark	Average Cost	$20 Benchmark	$30 Benchmark	$40 Benchmark	Average Cost
Less 5	$6,161,678	$5,540,318	$4,918,958	$110.50	$18,303,624	$17,048,304	$15,792,984	$165.81
5 to 200	28,468,519	18,828,441	11,076,066	43.78	20,253,205	12,391,045	4,528,885	45.76
200 to 650	6,424,898	737,517	42,434	25.77	1,417,209	0	0	22.36
650 to 850	2,073,525	174,633	0	25.70	0	0	0	18.56
850 to 2550	15,777,869	1,026,906	5,370	23.71	407,224	0	0	20.22
Greater 2550	4,184,777	286,831	0	21.93	5,226,037	0	0	21.61
Total USF Support	$63,091,267	$26,594,648	$16,042,828	$27.89	$45,607,298	$29,439,348	$20,321,868	$26.64